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Internal Wave Characterization and Analyses Research Supporting IWISE

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LONG-TERM GOALS

The long term goal of the project is to get a better understanding of the generation mechanism and characteristics of high frequency nonlinear oceanic internal waves in straits with a goal of predicting wave generation and travel times.

OBJECTIVES

The principal objective is to examine both in situ and satellite imagery of high frequency oceanic internal waves in the Straits in the Western Pacific (Luzon Strait, Surigao Strait) to determine the internal wave's distribution (geographic and temporal) and characteristics and use this information to support an empirical prediction scheme.

APPROACH

The effort makes use of the internal wave signatures recorded in satellite imagery (and collected in situ) to estimate internal wave phase speeds over a geographic region of interest. The phase speeds are in turn used to calculate the internal wave propagation times, where contours of propagation time represent the internal wave locations for a particular time since generation. The current effort is focused on improving the previously developed model by refining the criteria for when the internal waves are generated and understanding observed fortnightly and seasonal variations. The effort will also look for an empirical relationship between the internal wave signature observed in the imagery and the wave amplitude. The initial work is dedicated to internal waves originating in and around the Luzon Strait, but the approach is general in nature and has been used in other regions including the Surigao Strait, Sulu Sea, Celebes Sea and Andaman Sea.

WORK COMPLETED

In support of IWISE, an analysis of in situ observations and satellite imagery over the Luzon Strait and the eastern side of the Philippines is ongoing in order to identify, catalogue and characterize internal wave occurrences.

Report Documentation Page

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RESULTS

Satellite imagery has revealed the existence of high frequency nonlinear internal waves propagating eastward from the Luzon Strait into the Pacific Ocean. These eastern wave signatures differ significantly from the large solitary waves consistently observed propagating west from the Luzon Strait into the South China Sea. The signatures of the eastward propagating waves have been identified over a broad area between 123.5°E to 130°E longitude and 18°N to 24°N latitude and generally appear in packets or packet like groupings. The packets sometimes have a well defined rank ordered structure with the distance between the leading waves in the packet ranging from less than 500 m (early stage) to greater than 1.5 km (later stage). These eastward propagating waves have only been found in a relatively small number of the satellite observations over the Pacific Ocean east of the Luzon Strait. Figure 1 presents a spatial distribution map of the nonlinear internal waves east of the Luzon Strait along with an optical image showing an early stage packet.

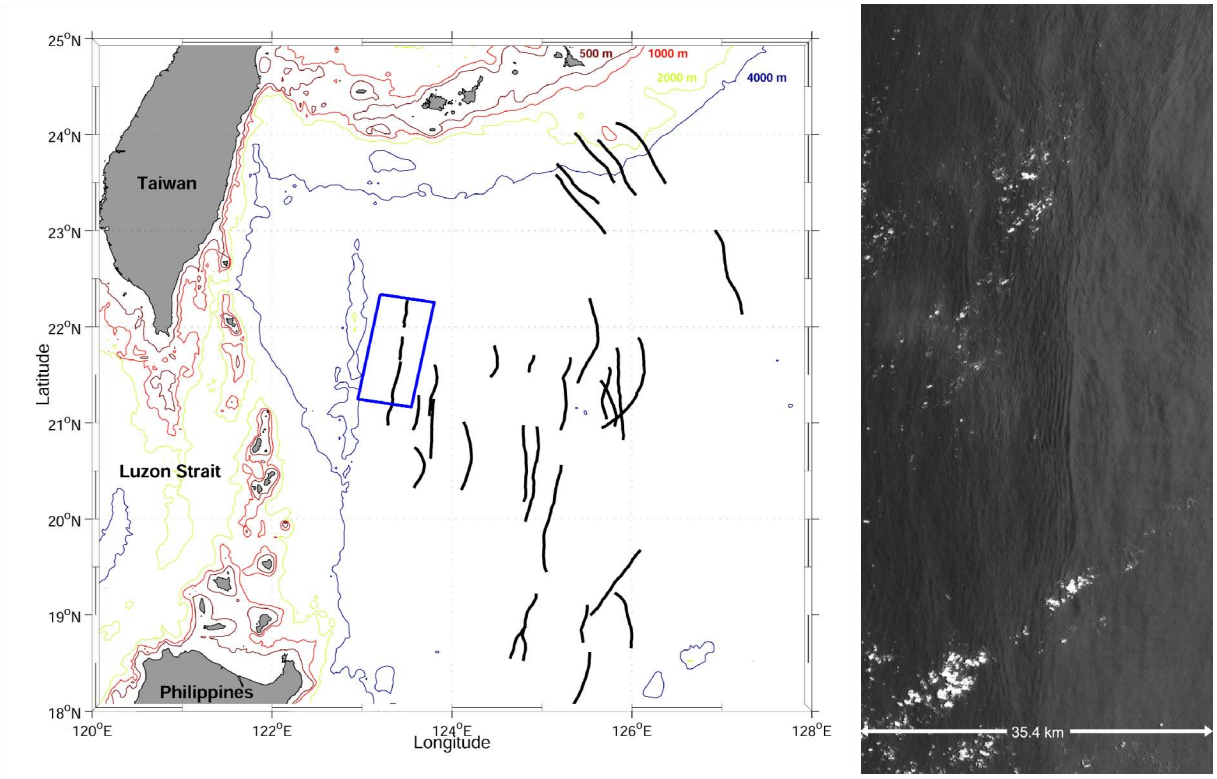

Figure 1. (Left) A spatial distribution map of high frequency nonlinear internal wave signatures observed east of the Luzon Strait. The black lines represent the leading wavefront of the eastward propagating nonlinear internal wave groups that have been identified in satellite imagery. (Right) A 15 meter resolution optical image showing an example of a nonlinear internal wave packet signature found east of the Luzon Strait. The image was acquired 22 May 2005 and centered at 123.4°E longitude and 21.8°N latitude and its location is outlined on the map.

In the eastern Philippines, internal wave signatures have been found at several locations in the Bohol Sea. Of principal interest are the internal wave packets which propagate southwest from the Surigao Strait (Figure 2-Left). Internal wave signatures of these waves are being digitized and input into the empirical model to determine phase speeds and wave propagation times. In addition, meter scale

resolution optical imagery has found large numbers internal wave signatures in Butuan Bay along northern Mindanao Island (Figure 2-Right). The wave packets contain very fine scale inter-wave spacing between roughly 10 and 100 meters. The packets appear to be generated by the outflow plumes (possibly tidally pulsed) of the 6 rivers along the southern and eastern sides of the Butuan Bay.

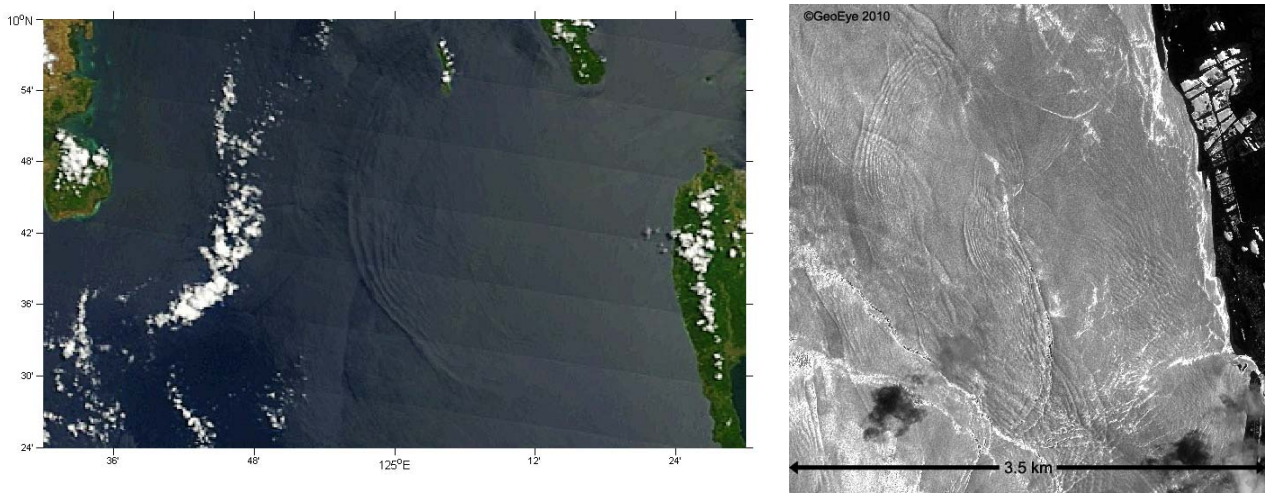

Figure 2. (Left) A 250 meter resolution MODIS true color optical image that shows an internal wave packet propagating from the Surigao Strait acquired on 9 June 2005 at 02:15 UTC. The image shows a well defined wave packet signature roughly 45 km from the Surigao Strait with the largest inter-wave spacing of approximately a kilometer. (Right) A 1.65 meter resolution GeoEye optical image of Butuan Bay acquired on 19 May 2009 at 02:17 UTC. The image shows more than a dozen internal wave packets in Butuan Bay with inter-wave spacing between 10 m to 100 meters.

IMPACT/APPLICATIONS

The internal waves identified east of the Luzon Strait and generated at the Surigao Strait have implications for the design of the 2011 IWISE field experiment. The "Luzon East" waves represent an important piece of puzzle in the generation processes taking place in the Luzon Strait. The Surigao Strait represent a second potential collection site for strait generated internal waves of different scale and generation mechanism than the Luzon Strait but is within close proximity to the main experiment site at Luzon. The discovery of internal waves in Butuan Bay begins to show the utility of meter scale resolution imagery to internal wave studies and represents new examples of plume generated internal waves.

PUBLICATIONS

Jackson, Christopher. R., and W. Alpers (2010), The role of the critical angle in brightness reversals on sunglint images of the sea surface, *J. Geophys. Res.*, 115, C09019, doi:10.1029/2009JC006037.

Buijsman, M. C., J. C. McWilliams, and C. R. Jackson (2010), East-west asymmetry in nonlinear internal waves from Luzon Strait, *J. Geophys. Res.*, doi:10.1029/2009JC006004, (accepted 12 July 2010) in press.

Jackson, Christopher R., Yessy Arvelyna and Ichio Asanuma (2011), High Frequency Nonlinear Internal Waves Around The Philippines, *Oceanography* (PhilEx Special Issue), (accepted October 2010) in press.